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Analysis of Spent Fuel Pool Flow Patterns Using Computational Fluid Dynamics: Part 2 – Partial Water Cases

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Executive Summary

In 2001, United State Nuclear Regulatory Commission (NRC) staff performed an evaluation of the potential accident risk in a spent fuel pool (SFP) at decommissioning plants in the United States [NUREG-1738]. The study was prepared to provide a technical basis for decommissioning rulemaking for permanently shutdown nuclear power plants. The study described a modeling approach of a typical decommissioning plant with design assumptions and industry commitments; the thermal-hydraulic analyses performed to evaluate spent fuel stored in the spent fuel pool at decommissioning plants; the risk assessment of spent fuel pool accidents; the consequence calculations; and the implications for decommissioning regulatory requirements. It was known that some of the assumptions in the accident progression in NUREG-1738 were necessarily conservative, especially the estimation of the fuel damage. Furthermore, the NRC desired to expand the study to include accidents in the spent fuel pools of operating power plants. Consequently, the NRC has continued the spent fuel pool accident research by applying best-estimate computer codes to predict the severe accident progression following various postulated accident initiators. The present report is Part 2 of a two part three-dimensional computational fluid dynamics (CFD) study to examine the flow patterns above, through, and around the spent fuel racks during accident conditions.

It has been conjectured that in a situation where a spent nuclear fuel storage pool had partially drained, adequate cooling of the uncovered portions of the fuel assemblies could occur via circulative natural convective flows penetrating into the assemblies from above the storage rack. In this scenario, air would be drawn in the top of an assembly. The air would flow down the assembly to the water level, reverse direction, and flow back out the top of the assembly, carrying away decay heat. A series of CFD calculations were performed to investigate the potential for such natural convective flows to develop.

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1. Introduction

It has been conjectured that in the situation where a spent nuclear fuel storage pool had partially drained, adequate cooling of the uncovered portions of the fuel assemblies could occur via circulative, natural convective flows penetrating into the assemblies from above the storage rack. In this scenario, air would be drawn in the top of an assembly. It would then flow down the assembly to the water level, reverse direction, and flow back out the top of the assembly carrying away decay heat. A series CFD calculations was performed to investigate the potential for such natural convective flows to develop. The methodology to perform the calculations is presented in Section 2. A description of the CFD model for each calculation is given in Section 3. Finally, the results of the calculations are presented in Section 4.

2. Methodology

The spent fuel pool CFD calculations were performed with the FLOW-3D® computer program [Flow Sciences, Inc.]. FLOW-3D® is a general-purpose software package for modeling the dynamic behavior of liquids and gases influenced by a wide variety of physical processes. The program is based on the fundamental laws of mass, momentum, and energy conservation, and has been constructed for the treatment of time-dependent multi-dimensional problems. FLOW-3D® is applicable to most any flow process.

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6. References

Boyd, C., "Predictions of Spent Fuel Heatup after a Complete Loss of-Coolant Accident," NUREG-1726, July 2000.

Chiffelle, R., et al., "Analysis of Spent Fuel Pool Flow Patterns Using Computational Fluid Dynamics: Part 1 – Air Cases," Sandia National Laboratories, Informal Report, April 2003.

Collins, T. E., and Hubbard, G., "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants," NUREG-1738, February, 2001.

Flow Sciences, Incorporated, "FLOW-3D, Version 8.0 User's Manual", 2002.

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